Journal of Engineering Technology Vol. 5: 15-19, 2017
ISSN 2231-8798

A Simulation Study of Electricity Generation by Using Rainwater Harvesting System

Najiyah Binti Saleh[1], Ammirrul Ikhmal Bin Ahmad Daud[1], Zarith Liyana Binti Zahari[2]
[1]Section of Electrical Technology
[2]Section of Electronic Technology

Universiti Kuala Lumpur British Malaysian Institute

Corresponding email: najiyah@unikl.edu.my

Abstract: The energy demand is growing because of the speedy technological improvement in various locations either in Malaysia or internationally. In order to stabilize energy demand, a number of renewable energy sources such as the rain, wind, biomass, hydro and solar energy which were able to help reducing the burden of fossil fuels. Since Malaysia is a country that has a relatively high rainfall each year, the country has the potential to apply the rainwater harvesting system (RWH) in which this system able to generate electricity in a small scale. RWH system is designed in which the rainwater will be collected and stored in a tank at high place and the rainwater will be released in a small pipe to generate electrical current by driven the Pelton wheel that act as the turbine. This paper presents a simulation study on the electricity generation by using the rain water harvesting system. By using this technique, any disrupted electrical supply can be resolved. The study was simulated using the Matlab and subsequently the mathematical modelling were developed to obtain the output of RWH system. This study will determine how much energy can be generated by applying the RWH system and the optimum performance with the best features of the systems.

Keywords: Rainwater harvesting system, Pelton wheel, Renewable energy, Matlab

1.0 INTRODUCTION

It's a reality today that the world short of non-renewable sources such as fossil fuel, coal and natural gas. It is because of the increasing demand of load from the consumers [1]. Increasing demand of the loads inherent the increment of electricity bills and then consumers need to pay more than often. The power demand in Malaysia keep on increasing year by year [1]. As the consequences, it is necessary to seek the potential renewable sources such as hydro, wind and solar energy to support the energy demand. Even though the non-renewable sources are able to generate more electrical power compared to the renewable sources [2], these renewable sources can help to reduce the burden of the fossil fuels.

The electrical energy is generated from the gas which contributed to 71.8% of the total energy generated, followed by coal (12.0%), hydro (10.1%) and oil (4.4%) [1]. Malaysia uses hydro power to generate the electricity because it emits no greenhouse gases to the atmosphere and its reserve has been replenished [2]. The rainwater harvesting (RWH) method is a way to gather the precipitation water and putting away into a tank to be used later for power generation.

The average overall rainfall in Malaysia is around 2000-3000 mm yearly meanwhile the average of temperature heat is 27 °C per year [3]. Malaysia climate has a tropical rainforest and is located at the equatorial region in which Malaysia has hot and humid weather throughout the year. Malaysia is experiencing 2 types of monsoon which are southwest monsoon and northeast monsoon. Normally, southwest monsoon came from dessert of Australia at late May to September. Meanwhile, Northeast monsoon originally from China and North Pacific at November to March. The northeast monsoon will bring more rainfall compared to the southwest monsoon. Every year, Malaysia experiencing a big flood due of the northeast monsoon. The east of the Malaysia most frequently having this nature disaster such as Terengganu. Hence, presumably that Malaysia has a potential to benefit the concept of RWH system based on its climate, a small scale of electricity can be generated at particularly area east of Malaysia.

2.0 MATERIALS AND METHODS

Block Diagram

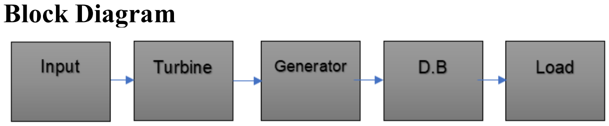

Figure 2.1: Rainwater harvested system block diagram

Journal of Engineering Technology Vol. 5: 15-19, 2017
ISSN 2231-8798

Figure 2.1 shows the block diagram for rain water harvested system. For the input, accumulated rainwater will be stored in a water storage area located on the roof of a three-storey building with a height of 50 meters. Then, the collected rain water will flow to the Pelton wheel turbine through the pipeline system. The Pelton wheel is selected as the turbine for this system due to its efficiency that could produce up to 80W as the output power. Later on the turbine will drive the generator in which the doubly fed electrical generators is selected due to its characteristics that is similar to the AC generator, but with extra features that allow it to run at speeds slightly above or below their natural synchronous speed. The power that is produced by the generator will be fed to the distribution board (D. B) in which it is expected the input for the distribution board would be 240V, 250A and 20kW. This is to accommodate the load in a 50m building.

The Proposed Process of RWH System

Figure 2.2 shows the proposed process of RWH method that could be developed based on this simulation study. The rain water that has fallen into the gutter will be filtered first before it is stored in a water storage tank. Then, the rain water will continuously flown into the small pipeline regardless of the level of water in the tank. The small pipeline eventually will maximize the pressure of water flow and subsequently drive the turbine. Then, the generator connected from the turbine will be rotated and generate power. The power that has been generated from the rotated generator will be fed into the distribution board and subsequently power up the load.

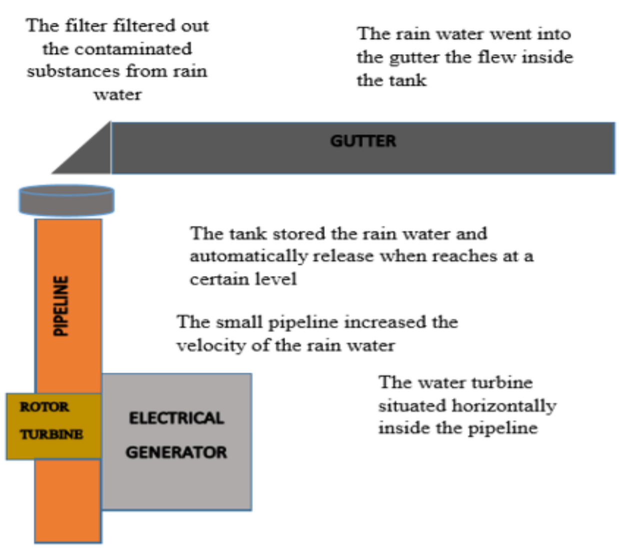

Figure 2.2: Proposed (RWH) method

Circuit Diagram of RWH System

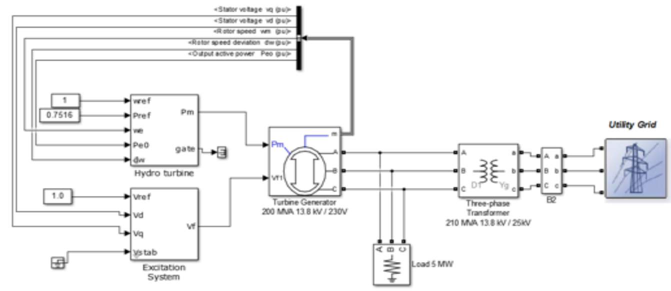

Figure 2.3: Circuit diagram of (RWH) system

Figure 2.3 shows the whole circuit diagram of RWH system in MATLAB/SIMULINK software. The input of the circuit diagram is the strain of water which will generate the mechanical energy for the Hydro Turbine circuit diagram. The excitation device will provide excitation energy for the synchronous generator and alter its terminal voltage in producing mode. After that, the output from hydro turbine is connected to the generator so that the mechanical energy can be converted into electrical energy. Later on the generator is connected to the three phase transformer to subsequently power up the load.

Mathematical modelling of (RWH) system

The Rain water harvesting system consists of several main components in order to obtain the supply that could power up the load with approximately ±230V. The main components for this system are the hydro turbine and turbine generator. Therefore, several calculations need to be performed to determine how much energy can be generated.

To obtain the water flow pressure from the 5 metre of height that fallen into the turbine, the formula [5] of Pressure is applied as in (1)

$$\text{Pressure, P (kpa)} = p \times g \times h \tag{1}$$

Where: p= Fluid density (1000kg/ m^3)
g= Acceleration due to gravity (9.81m/s^2)
h= Height of the fluid above point of measurement (m)

The velocity of the water that flow in the pipeline into the turbine can be obtained by using the formula [6] of (2)

$$velocity\ ,speed\ \left(\frac{m}{s}\right) = \frac{\sqrt{2P}}{p} \tag{2}$$

Where: v= Velocity (ms^{-1})
P= Pressure (kPa)
p= Fluid density (1000kg/m^3)

Journal of Engineering Technology Vol. 5: 15-19, 2017
ISSN 2231-8798

Then, the torque of the hydro turbine and the volume of flowrate for the rainwater can be determined based on the formulae [4] shown in (3) and (4) respectively.

$$\text{Torque (N.m)} = \frac{P \times Q \times 36.77}{rpm} \quad (3)$$

Where: P= Pressure (kPa)
Q= Liquid flow rate (m^3/s)
rpm = Revolution per minute for turbine (1500rpm)

$$\text{Volume of flowrate, Q } (m^3/s) = \frac{\text{Volume of water}}{time} \quad (4)$$

Where: Volume of water (m^3) = 200 liters = 0.2 m^3
Time = 1 hour (3600sec)

The output power and current for the RWH system can be obtained based on equation [4] (5) and (7) respectively while equation [5] (6) can be used to determine the angular velocity of the generator.

$$Pout = T \times \omega \quad (5)$$

Where: Po = Power output
T =Torque
ω = Angular velocity

$$\text{Angular velocity, } \omega = \frac{2\pi N}{60} \quad (6)$$

Where: ω = angular velocity
N = rotation per minute (rpm)

$$I = \frac{P}{V} \quad (7)$$

For example, based on the mentioned equation above, the height of 5-meter rain water that fed into the turbine will produce 10.58W of output power and 46mA of output current. Table 2.1 below shows the obtained data on the power produced when the stored rain water that flows in the small pipeline falls from the height of 5 metre and until 50 metre to subsequently drive the turbine.

Table 2.1: Power produced from the turbine up until 50 metre of height for 1 hour

Height (m)	Pressure (kPa)	Speed of turbine (m/s)	Torque (N.m)	Voltage (V)	Current (A)	Power (W)
5	49.05	69.37	67.33	230	46m	10.58
10	98.10	138.73	134.67	230	91.96	21.15k
15	147.15	208.10	202.00	230	142.17	32.70k
20	196.20	277.47	269.33	230	183.96	42.31k
25	245.25	345.84	336.67	230	229.91	52.88k
30	294.30	416.20	404.00	230	275.91	63.46k
35	343.35	485.78	471.33	230	321.91	74.04k
40	392.40	554.94	538.67	230	367.87	84.61k
45	441.45	624.30	606.00	230	413.87	95.19k
50	490.50	693.67	673.33	230	459.87	105.77k

Case studies

There are several situations or case of studies have been performed by using different parameters for the RWH system. All the case of studies have similar setting of height and pressure but different in the operation of time. This is to determine the power that the RWH system can be generated by simulating using Matlab software. Table 2.2 below shows the parameters used to simulate the RWH system.

Case of study	Rain water harvesting system (RWH)		
	Height (m)	Pressure (kpa)	Operation time (hour)
1	50	490.50	30 minutes
2	50	490.50	2
3	50	490.50	6

Table 2.2: Parameters used to simulate the RWH system

Journal of Engineering Technology Vol. 5: 15-19, 2017
ISSN 2231-8798

3.0 RESULTS

Case Studies 1

,

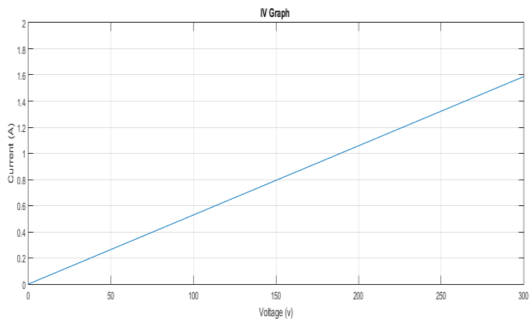

Figure 3.1: Graph for case of studies 1

Figure 3.1 shows the graph for case of studies 1. The graph shows the value of voltage and current in the RWH system after the simulation. The power was increasing as long as the current and voltage increasing. The power output from the simulation was 52.88kW and the current was 232.095 A for 30 minutes' of operation time. The power that generated was high due to only short time taken for the RWH system to operate. Therefore for the case study 1, the RWH system will produce high power and current within 30 minutes.

Case Studies 2

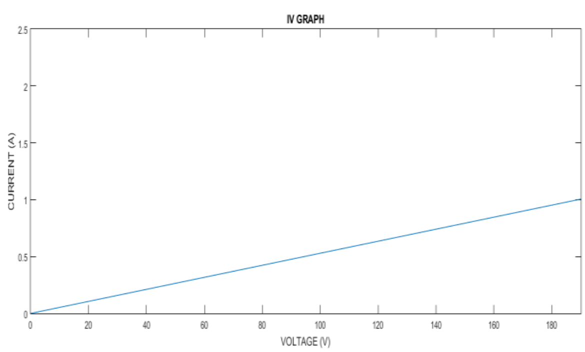

Figure 3.2: Graph for case of studies 2

Figure 3.2 shows the graph for case of study 2. The graph shows the value of voltage and current for the simulated RWH system. The power keep on increasing when the current and voltage increase but it is lower compared to the case study 1. The power output from the simulation was 31.035kW and the current was 66.23 1A for 2 hours' of operation time. The power that generated was low because it takes longer time for the RWH system to operate. Hence for the case study 2, the RWH will produce low performance compared to the case study 2 if it is operated within 2 hours.

Case Studies 3

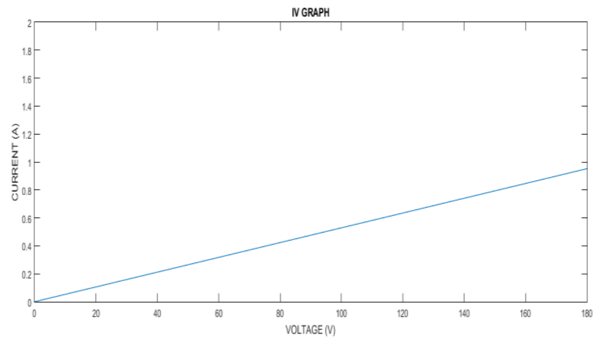

Figure 3.3: Graph for case of studies 3

Figure 3.3 shows the graph for case of study 3. The graph shows the value of voltage and current in RWH system that were simulated by using Matlab. The power is increasing when the current and voltage increase. However, this value of power is the lowest as compared to case of study 1 and 2. The output power from the simulation was recorded to be 21.54kW while the current was 32.0135A for 6 hours of RWH operation time. The power that generated was the lowest due to it takes a very long time for the RWH system to operate. Therefore, it takes about 6 hours for the RWH system to produce the lowest output power and current compared to previous case of studies.

4.0 Discussion

Case of study	Operation time (hour)	Rain water harvesting system (RWH)		Power (kW)	Current (A)
		Height (m)	Pressure (kpa)		
1	30 minutes	50	490.50	52.88	232.095
2	2	50	490.50	31.035	66.23
3	6	50	490.50	21.54	32.0135

Table 4.1: Overall results based on the simulated RWH system

Table 4.1 shows the overall results based on the simulated RWH system. The longer time it takes to operate the RWH system, the lower output power that will be produced. This is because the load will consume more power when the RWH system operate for a longer time. It is suggested that the system operation to be hold for a moment to obtain longer time for the RWH system to operate. By this way, the power and current will be more stable and can be supplied for a longer time to the load.

5.0 CONCLUSION

In conclusion, it is suggested to use the Pelton turbine in the RWH system since the turbine could generate high mechanical energy even though it receives low pressure from the water stream in the small pipeline. The simulation of the RWH system is considered for ideal condition only. Although the energy produced was not big enough to supply all the building appliances but it still can be applied during emergency condition for the important appliances to keep on functioning. Therefore, this simulated RWH system can be applied to the real domestic building. The RWH system is one of the best method of renewable energy that can be applied in Malaysia as this country receives consistent rainfall annually.

REFERENCES

[1] A. R. Mohamed and K. T. Lee, "Energy Policy for Sustainable Development in Malaysia," *The Joint International Conference on Sustainable Energy and Environment (SEE)*, pp. 940-944, December 2004.

[2] M. S. N. Samsudin, M. M. Rahman and M. Abdul Wahid, "Power Generation Sources in Malaysia: Status and Prospects for Sustainable," Journal of Advanced Review on Scientific Research, Vol. 25, pp. 11-28, September 2016.

[3] S. Ibrahim, N. S. Sahlan and M. S. Jit Singh, "Kajian Hubung kait Tekanan dan Suhu Terhadap Taburan Kerpasan di Malaysia Ketika Fenomena ENSO," Jurnal Kejuruteraan, pp. 53-64, 2016.

[4] G. Yadav, and K. Chauhan, “Design and Development of Pico Micro Hydro System by Using House Hold Water Supply,” pp. 114–119, 2014.

[5] T. C. Yan, T. Ibrahim and N. M. Nor, “Micro hydro generator applied on domestic pipeline,” Proceedings of the 2011 International Conference on Electrical Engineering and Informatics (ICEEI), pp. 5090 – 1798, 2011.

[6] R. Uhunmwangho, "Small Hydropower for Sustainable Development”, The Pacific Journal of Science and Technology, pp. 535-543, 2009.